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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

RMD

CASCADEL TREE SELECTION PLOT

STUDY OF LOSSES AND APPLICATION OF TREE SELECTION THEORY

SEASON OF 1931

PROGRESS REPORT

by

G.R. STRUBLE
Assistant Entomologist

Berkeley, California
May 11, 1932

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ABSTRACT

The Cascade1 tree selection plot, 10 chains wide by 80 chains long, and located in the Sierra National Forest near Northfork, Calif., was established in 1926 by the Bureau of Entomology to secure data pertinent to selection of ponderosa pine by the western pine beetle. Annual records of loss have been kept since that time.

During 1931 the worst epidemic of the western pine beetle recorded for this region took place, and many trees were killed on the selection plot. Losses on the plot from 1923 to 1931 amounted to 13 per cent of the total number of trees and 15 per cent of the total volume; the 1931 loss amounted to 35 per cent of the trees and 46 per cent of the volume killed during the 1923-1931 period. The infestation during the 1931 epidemic was centered near the middle of the 80-acre plot, with insignificant damage to either end. This infestation presented an opportunity (1) to bring up to date the record of insect losses on the 80-acre plot; (2) for a comparison of localized infestations with non-infested localities; and (3) an opportunity to study the validity of the growth-rate selection theory during an epidemic. Data were secured in November, 1931, when a Forest Service control project of the Cascadel area was under way. For this reason it was necessary to complete the insect record before influences were set up by control measures.

Studies were concentrated on three 10-acre units, viz., (1) south 10 acres, where losses were endemic in 1931; (2) middle 10 acres, where epidemic conditions prevailed in 1931; and (3) north 10 acres, where no losses aside from topkilling occurred in 1931. Comparisons of site, exposure, growth rate, increment, loss and tree selection by growth rate were made between these three units. In the following table these comparisons are summarized. No attempt was made to compare these factors on the remaining 50 acres between the three mentioned units, due to the limited time available for this study.

Comparisons	South 10 Acres	Middle 10 Acres	North 10 Acres
Living Stand 1923	Trees - - - -225 Vol.BF - 170,076	Trees - - - 182 Vol.BF -153,060	Trees - - - 182 Vol.BF -111,087
Site	II-III	III	II
Exposure	Steep north	Ridge; gentle north and south	Gentle southwest
Growth Rate-width of 1930 ann.ring	79% of stand below 1 mm.	73% of stand below 1 mm.	42% of stand below 1 mm.
Increment 1923-31 % of 1923 volume	5.1	4.8	7.2
Losses,1923-1931	Trees - - - -18 Vol.BF - -3,670	Trees - - - -92 Vol.BF - 82,320	Trees - - - - 7 Vol.BF - -4,610
Av.growth rate of trees sel.by D.b. 1 yr.before death compared with av. growth of green trs.for same year	1931 D.b. trees .30 mm.less gr'th than green trees in 1930	1931 D.b. trees .25 mm.less grow. than green trees in 1930	1929 D.b. trees 1.10 mm.less gr'th than green trees in 1928
Living stand remaining, 1932	Trees - - - 207 Vol.BF -169,058	Trees - - - -90 Vol.BF - 75,107	Trees - - - 175 Vol.BF -114,698
Gr.trs.topkilled 1931; no further attack	0	12	7

It is concluded (1) that site and exposure were in favor of the infestation becoming centered on the middle 10 acres; (2) that D.b. selection of trees by growth rate was largely a matter of chance on the south and middle units, due to a larger number of slower-growing trees, while there was definite selection for slower-growing trees on the north unit; (3) that more trees were topkilled on the middle unit, which assisted in setting up an attraction there to the western pine beetle.

Certain theories have been advanced which help to explain the localization of attacks: (1) that slope and exposure are important in limiting moisture supply during an epidemic year, regardless of growth rate, and influence the beginning of an attack in one locality in preference to another; (2) that light intensity or temperature may have been important to the beginning of an attack; and (3) that topkilling by Ips is largely responsible for sudden weakening of trees and making them susceptible to attack, thus causing a center of infestation.

CASCADEL TREE SELECTION PLOT
STUDY OF LOSSES AND APPLICATION OF TREE SELECTION THEORY
SEASON OF 1931

PROGRESS REPORT

INTRODUCTION

The Cascadel tree selection plot is located in the Sierra National Forest at an elevation of 3500 feet, in a fairly typical west-side ponderosa pine type forest. Most of the plot has a southwest exposure, except for parts which face to the north on account of several creeks and draws. It extends over a narrow strip of forest, 10 chains wide by 80 chains long, in a north and south direction to take in the middle of the northwest quarter of Section 22 and the southwest quarter of Section 15, T 8 S, R 23 E (see map). A small percentage of incense cedar, sugar pine and white fir are present in addition to the ponderosa pine.

This plot was laid out by Person and Wagner between September 3 and 17, 1926, the first of three plots to be used for a long-time study on the classes of trees selected by the western pine beetle. A record of losses had been kept on an area embracing this plot since 1919, so that a complete record of loss on the selection plot was obtained from that date. Selection by growth rate, diameter, tree class, site, and length and width of crown were considered by Person* as most significant on this plot and two other plots located in northern California. Growth rate was found to be the best index to tree selection, since the largest percentage of trees killed by D.brevicomis in all his studies were in the slower-growing, less vigorous group. Selection by diameter was found to be important in diameters from 18 to 32 inches; below and above this diameter range the number of trees selected was less significant.

This study was started at the suggestion of J M. Miller during November 1931, when a Forest Service control project was well under way in the Cascadel basin, to check the worst epidemic on record for this region of the western pine beetle. Many trees were killed on the tree selection plot, with the heaviest concentration near the middle. The need for further study on this plot was apparent (1) to bring up to date the annual record of infestation; (2) to explain the concentration of trees killed in 1931 in the middle of the plot in preference to either end; and (3) to determine whether in the 1930-1931 epidemic selection by growth rate was still valid. Immediate attention to these studies was necessary before the influence of control work had set in.

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*PERSON, R.L. Tree Selection by the Western Pine Beetle. Journal of Forestry, May 1928; Vol. 24, No. 5, pp. 564-578.

The data presented in the following pages cover the period from 1923 to 1931. Losses in general over the entire plot will first be considered, and later a more detailed study of three 10-acre units will be taken up to determine the underlying causes of localized infestations during the 1930-1931 epidemic.

RECORD OF LOSSES, 1923 TO 1931

Tables 1 and 2, which follow, and Figures 1 and 2, at the end of this report, give a fairly clear idea of the history of the Cascadel plot for the past nine years, during which time two epidemics of D.brevicomis have taken heavy toll, the last by far surpassing the first.

Table 1

D.b. and other losses in ponderosa pine since 1923
on Cascadel Tree Selection Plot

Year	D.b.Losses: Trees	Volume	Flathead Losses: Trees	Volume	Other Losses: Trees	Volume	Topkilled (ips): Trees	Volume
1923	15	6,940						
1924	3	1,460					1	710
1925	27	30,420						
1926	9	4,600	1	60	1	330	3	1,450
1927	28	20,630			2	1,540		
1928	5	2,820						
1929	15	10,840					2	2,300
1930	24	21,030	1	40	1	1,260	4	4,800
1931	65	80,690	1	50	5	3,610	30	26,300

Table 2

Summary of Stand on Plot and Losses 1923 to 1931

	Trees	Volume	Trees	Volume
Living stand, 1923			1,452	1,148,030
D.b. losses, 1923-1931	167	131,030		
Other losses, 1923-1931	10	6,490		
Total 1923-1931	197	137,520	197	137,520
Living stand left 1931			1,255	959,560
Living topkills, 1923-1931			39	25,250
Good green trees left, 1931			1,216	983,300

STUDY OF LOCALIZED INFESTATIONS, 1930-1931

Notes, records and other data were limited to three 10-acre units of the 80-acre plot for the purpose of comparing different factors significant to the preference shown by D.brevicomis for the middle part of the plot. These units are designated South, Middle and North 10 acres respectively. Individual records of trees on each unit, which were taken in 1926, were separated by locating them on a detailed map of the selection plot in order to get pertinent data to the description of each tree. Cores were taken by means of an increment borer from all remaining green trees to compare growth rate and amount of increment

from 1923 to 1931. Cores were also taken from all trees killed in 1931 and from as many as possible that were killed before that time. The following significant points will be taken up in order of their importance on these three plots:

1. Comparison of sites
2. Comparison of losses
3. Comparison of growth compensation for losses
4. Comparison ofgrowth rates of green and insect-killed trees
   a. By Keen's age classification
   b. On each plot in general
   c. Distribution of green trees left and 1931 D.b. trees by width of 1930 annual ring
5. Distribution of green and insect-killed trees by diameters
6. Discussion

No detailed studies were conducted on the remaining 50 acres between the three units, due to limited time for this study.

Comparison of Site and Exposure

1. South 10 acres. This unit occupies the south end of the 80-acre plot near the bottom of a slope, site II to III. The stand is scattered toward the east side of the plot and quite dense on the west side. Most of the trees are medium-sized, with a range in diameter of 12 to 44 inches d.b.h.

2. The middle 10 acres is located near the center of and slightly south of the center of the 80-acre strip. The plot is on a ridge having gentle to steep north and south exposures--site III. Trees are larger in diameter but shorter; the stand is more open.

3. North 10 acres. This plot occupies the north end of the 80-acre unit, site II, and most of it faces to the southwest, with slopes more gentle than in either of the other units. Although there is considerable drainage toward this plot it gets quite dry during the summer. Trees are smaller but more vigorous than on either of the other units.

Comparison of Losses

On the south and north ten acres the trees killed by insects were well distributed, with no particular spotting or group killing. The middle plot, however, contained several large groups with centers near the top of the ridge and extending well over both exposures, especially on the north.

Table 3. Total Losses in Volume Bd.Ft. and Number of Trees, 1923-1931

Unit	D.b.-Killed		Killed by Flatheads		Other Losses		Topkilled	
	Trees	Volume	Trees	Volume	Trees	Volume	Trs.	Volume
South 10	15	9,610	1	60			1	120
Middle 10	92	65,380			2	3,560	13	18,180
North 10	7	4,510					10	8,320

The foregoing table shows (1) that the heaviest damage was done to the middle plot; in fact, losses on the north and south units are insignificant in comparison; (2) that D.brevicomis was the primary insect, causing the death of trees; (3) that losses due to flatheads and other causes are insignificant.

The table to follow and Figures 3, 4 and 5 at the end of this report give a year-by-year comparison of losses due to the western pine beetle from 1923 to 1931. In Figure 3 losses are shown both in board feet volume and number of trees for each plot. The same sort of comparison is shown in Fig. 4, but is based on per cent of total stand. Fig. 5 is a comparison of losses in per cent of total number of trees, and is shown as a cumulative column, the losses for each successive year adding to the total.

Table 4. Losses Due to D.brevicomis, 1923-1931

Year	South 10 Acres: Trees	Volume	Middle 10 Acres: Trees	Volume	North 13 Acres: Trees	Volume
1923			3	2,560		
1924	2	1,360	1	100		
1925	4	3,740	10	8,260		
1926			6	5,130		
1927	2	160	5	5,720		
1928			1	1,460		
1929	3	1,040	8	5,200	3	1,800
1930	3	2,050	12	9,970	4	2,710
1931	1	1,260	46	48,940		
Totals:	15	9,610	92	85,320	7	4,510

Comparison of Increment and Losses

The purpose of this study was to determine to what extent the amount of growth each year on each plot would offset loss due to insects. Data were secured by taking cores from all green and insect-killed trees on each plot and measuring the width of annual rings during the period 1923 to 1931. Cores from trees which were killed before 1931 included the measurement of rings between 1923 and the time of death. All measurements were made by a standard core-measuring instrument which is accurate to one-hundredth of a millimeter.

The methods used in calculating increment in terms of volume (board feet) are briefly as follows: 1. Original volume for each two-inch diameter class was based on 1926 measurements. 2. Annual ring width for each year from 1923 to 1931 was recorded separately for all trees in each diameter group and the average growth was figured for each year. 3. The average ring width for each year was changed to per cent of total growth 1923-1931. 4. Basal area for 1923 was figured by subtracting radial increase 1923 to 1926 from the known 1926 radius. 5. Basal area for 1931 was figured by adding the radial increase from 1927 to 1931 to the known 1926 radius. 6. The difference between 1923 and 1931 basal areas was obtained and changed to per cent increase in growth. 7. The per cent increase was then applied to volume for each diameter

group. 8. The volume increase for each diameter group was next divided among the years 1923 to 1931 by applying the per cent increment for each year in each diameter group. This gave the amount of volume increase in each 2-inch diameter group, from which the total volume increase for each year could be figured.

The results obtained by the above methods of figuring are only approximate, but reasonable enough for this region. In the table which follows is given a year-by-year comparison on each 10-acre unit of the amount of growth, loss and green volume left at the beginning of each year. This comparison is shown graphically in Figures 6, 7 and 8.

Table 5. Comparison between green volume increment, loss and net gain or loss on each 10-acre unit

	Year	Total Green Volume	Increment	Loss	Net Gain	Net Loss
South 10 Acres	1923	170,076.8	1,712.9		1,712.9	
	1924	171,769.7	889.7	1,360		470.3
	1925	171,219.4	1,116.2	3,740		2,623.8
	1926	168,695.2	1,004.4	60	944.4	
	1927	169,640.6	920.7	160	830.7	
	1928	170,470.7	1,046.6		1,046.6	
	1929	171,517.3	652.7	1,040		387.3
	1930	171,130.0	630.9	2,050		1,419.1
	1931	169,710.9	657.4	1,310		652.6
	1932	169,058.0				
Middle 10 Acres	1923	153,060.2	1,287.1	2,550		1,262.9
	1924	151,797.3	784.8	100	684.8	
	1925	152,482.1	854.4	8,260		7,405.6
	1926	145,076.5	883.5	3,130		2,246.5
	1927	142,760.0	850.5	5,700		4,861.5
	1928	137,898.5	921.7	1,460		538.3
	1929	137,360.2	639.9	5,290		4,650.1
	1930	132,710.1	600.9	9,970		9,369.1
	1931	123,341.9	606.3	48,840		48,233.7
	1932	75,107.5				
North 10 Acres	1923	111,087.6	1,497.7		1,497.7	
	1924	112,585.3	759.8		759.8	
	1925	113,345.1	901.4		901.4	
	1926	114,536.5	963.5		963.5	
	1927	115,890.0	1,004.3		1,004.3	
	1928	116,294.3	965.5		965.5	
	1929	117,259.8	690.2	1,800		1,109.8
	1930	116,150.0	630.4	2,710		2,079.6
	1931	114,070.4	612.0		612.0	
	1932	114,682.4				

Growth Rate Selection

1. General comparison between green and insect-killed trees. Figure 10 illustrates the comparative growth rates on the three 10-acre units between 1925 and 1931. The curves are based on average ring widths in millimeters of green and insect-killed trees. The number of trees forming the basis for average growth rate is indicated at each point on the graph.

The graph shows (1) that the average growth rate of green trees for the south unit was less than either the middle or north unit, the growth rate of the north unit being considerably faster than either of the other units; (2) that on all three plots growth had slowed down over the period, so that in 1931 growth was less than 1 mm. on the south and middle units, but well above 1 mm. on the north unit; (3) that insect-killed trees were slower-growing than green trees on all plots, but the difference in growth is great enough only on the north unit to warrant significant selection by D.b. for slow-growing trees.

2. Comparison of growth by Keen's age classes--Figure 9. Four age classes are represented for each 10-acre unit. The growth rate in each class is compared for each plot for green and insect-killed trees. The number of trees from which average growth was computed is indicated at each point on the graph. The following points are significant: (1) The growth curve of green trees is slowest on the south plot and fastest on the north plot for classes 1, 2 and 3; class 4 is about the same for all three plots. (2) The growth rates of insect-killed trees in classes 1 and 2 are slower on all three plots, but a wider difference is evident for the south and north plots. (3) The trees selected by D.b. in classes 3 and 4 on the middle plot were growing at about the same rate as green trees until 1929. From that time the growth of D.b. trees killed in 1931 continued to decrease, while the green trees showed some increase in growth. On the north and south plots the growth rate of trees killed by insects was slower for most of the period of comparison. (4) More trees were killed in classes 3 and especially class 4 on the middle unit, because of a greater number of trees in these classes susceptible to attack.

3. Distribution of green trees left and 1931 D.b. trees by width of 1930 annual ring. The number of green and insect-killed trees in each five-tenths of a millimeter range in growth are compared on each 10-acre unit from 0 to 2 millimeters. All trees with a growth above 2 millimeters are treated as a unit. In the following table this distribution is shown. Figure 12 shows the distribution in per cent of total number of trees.

Table 6. Distribution of trees by .5 millimeter groups

1930 ring width: millimeters	South 10 acres: Green:	1931 D.b.:	Middle 10 acres: Green:	1931 D.b.:	North 10 acres Green:	1931 D.b.
0 to .5	118	1	37	22	45	0
.6 " 1.0	70	[illegible]	29	20	38	0
1.1 " 1.5	25	0	10	3	40	0
1.6 " 2.0	6	0	5	10	28	0
2.1 " 5.0	1	0	6	0	26	0

On the basis of the above comparison certain significant points are brought out with regard to tree selection: (1) the proportion of slower-growing trees to faster ones on each plot (considering from 0 to 1 millimeter as slow and above 1 millimeter as fast) is 8 to 1 on the south plot, 5 to 1 on the middle plot and 9 to 10 on the north plot; (2) heavy losses occurred in the slow-growing groups on the middle plot, but were negligible and lacking respectively in these groups on the south and north plots; (3) in the faster-growing groups, losses amounted to 12 per cent on the middle plot, while no losses in these groups occurred on the south and north plots.

Looking at the middle plot alone (Figure 12) it appears at first that a definite selection is shown for the slower-growing groups between 0 and 1 mm. In comparison to the total number of trees in each group, 38 per cent of the slower-growing trees were killed, while 12 per cent of the faster-growing group were killed. This appears to be significant selection for the slower-growing trees; but the number of trees in the slower-growing group is five times that of the faster-growing group. Chance selection, therefore, is strongly in favor of the slower-growing trees.

Relation Between Diameter Classes and Trees Selected

The distribution of trees by 6-inch diameter groups is shown by Figure 11, in which the number of trees in each group is figured in per cent of total number of trees for each 10-acre unit. On south and north plots the losses are so small that selection by diameter is insignificant. The losses on the middle plot, however, show a higher preference for trees from 18 to 34 inches in diameter, which is the normal preference according to Person's data.

Looking somewhat further into the distribution of diameters on the three plots, one thing stands out--that a greater number of trees of susceptible diameter are on the middle plot in comparison with either of the others, especially the north plot. The north plot in particular has a much greater number of trees in the smaller-diameter groups.

DISCUSSION

Slope and exposure may be considered to have more to do with limiting the moisture supply, and as a result making a greater difference in tree vigor on the three 10-acre units, regardless of growth rate during a drought period. Data presented show a slower average growth rate for the stand on the south 10 acres than on the middle, yet the losses were negligible in comparison. To say that the answer is due to more moisture in the soil in the south 10 acres may be correct, but we have no data to prove it. One thing is certain in comparing the two plots: the south plot is on a steep north slope where there is less chance for evaporation of soil moisture, in contrast to the middle plot, which occupies a ridge having both south and north exposures. Here the stand is open and evaporation of moisture from the soil was undoubtedly much greater, especially toward the top of the ridge and on the south slope.

The trend of infestation on the middle plot is also in favor of the moisture theory. As brought out earlier, groups of trees were killed first near the top of the ridge, and from there the infestation spread in toward both slopes, especially to the north. The reasons why it extended to the north are not at first easy to understand solely on the basis of the moisture theory; but when it is known that the greatest number of trees susceptible to insect attack were found there the explanation becomes somewhat simplified. The larger trees on this plot of susceptible diameter range were located here--trees which under endemic circumstances would not be attacked. But when the beetles became so concentrated along the ridge, due to a marked decrease in resistance there, they bred up in such numbers that the more susceptible trees nearby were attacked. This fact is also emphasized by Fig. 10, which does not show a marked difference in growth between green and insect-killed trees. Growth rate alone was evidently not responsible for susceptibility when the vigor of the stand was brought down so rapidly during the 1930 and 1931 drought years.

The reasons for light losses on the north unit are easy to understand, since the growing conditions in general are better. Slopes are more gentle and it is situated near the bottom of a high ridge, where there would be a better infiltration of water by underground drainage. The growth rate of green trees here is considerably faster than on either of the other two plots in the lower-diameter ranges, a fact which is also indicative of better growing conditions. Here also a definite selection was shown for the trees of slow growth rate. Diameter of trees is another important consideration on this plot, since the greatest proportion of trees are in the small-diameter range (Figure 11) and are therefore less susceptible to attack since they are younger, more vigorous trees.

Although the trees killed by D.b. on the middle 10-acre unit were slower growing in 1930 than the green trees remaining, this does not necessarily prove that a preference was shown for the slower-growing trees, since they were much in excess of the faster-growing ones. The chances of selection are so in favor of the trees of slow growth rate that it is logical that most of the trees in this class should be killed. It is therefore unsafe to conclude that slower growth rate was responsible for the trees selected here.

Aside from the moisture theory, light intensity or temperature may have had an important influence on the infestation of the middle 10 acres. There is no doubt that infestations are localized, and often on stands apparently more resistant than others near by. But whenever western pine beetle attacks are centered in a given locality a definite attraction is set up, causing other beetles in flight to settle there. They then breed up in numbers sufficient to kill surrounding trees, preferring usually the slower-growing ones.

Another factor of very great importance, and one which will bear considerable more study, is the influence of topkilling by Ips on D.b. attacks. Person has emphasized the importance of topkilling on epidemics of the western pine beetle, and it has been repeatedly noticed that preceding epidemics an abnormally large number of trees were topkilled. On the tree selection plot during the 1931 epidemic 2 per cent more trees were topkilled than D.b.-killed trees; and it is not definitely known how many of the D.b.-killed trees were first topkilled. Stem analyses made on trees felled during November, 1931, showed that Ips confusus was present in about 99 per cent of the cases. The question remains whether Ips attacked the top before D.b. made its attack or vice versa. However, enough damage was done to the tops of trees that were attacked first to set up an attraction to the western pine beetle, and as a result build up centers of infestation.

SITE MAP

PART OF CASCADEL AREA - SIERRA N. F.

——TREE SELECTION PLOT BOUNDARY

---BOUNDARY REGIONAL SURVEY PLOT 7

COMPASS AND PACING 8" = 1 MILE

MAPPED BY H. L. PERSON 1925

Legend
Site boundaries
Roads
Fences
Streams (running)
" (dry
Ridges
Cliffs

16 15 21 22

NORTH CASCADEL TREE SELECTION PLOT

MIDDLE

SOUTH

REGIONAL SURVEY PLOT 7

Pasture
Orchard
Cascadel Ranch
Swamp
Y.P. Poles
White Rock Creek
Steep & Rocky
Steep & Rocky
Tributary
Pasture
Three Barn
Orchard
Y.P.-Oak-Cedar S.P.
Fair stand Y.P.
Field
Brush
Heavy stand Y.P.
Y.P. Poles
Cave Creek
Reproduction
Scattered Y.P. Poles
Brush
Y.P. Poles
4 Oak
Mature Y.P.
Scattered Y.P. & Poles
Brush
Brush & Rocks
Few Y.P. Poles
Scattered Y.P.
Brush & Oak
Very Brushy
Brush & Oak
Brush
Scattered Y.P. & Brush
Open Stand Y.P.
Open stand Y.P.
Bear Clover
Scattered Y.P. Oak-Brush
Heavy Stand Y.P.
Y.P. & Oak
Scattered Y.P.
Y.P.-Oak-Cedar
Thin stand Y.P. Brush & Oak
Steep 10% S.P.
Brush
Brush
Fair stand Y.P.
Y.P. Brush-Oak
Y.P. Poles
Open stand Y.P.
Y.P. Poles & Oak

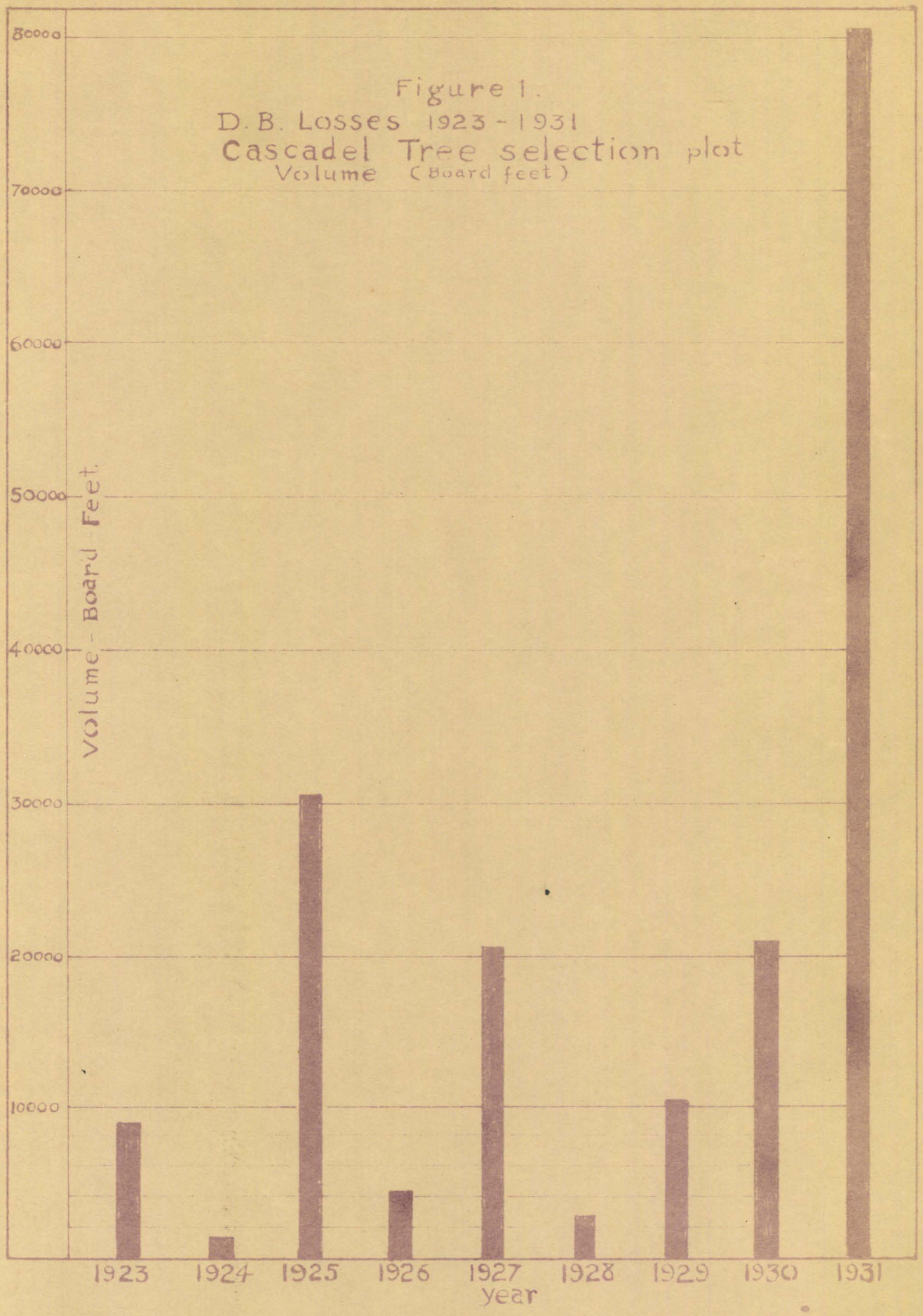


Figure 1.
D. B. Losses 1923 - 1931
Cascadel Tree selection plot
Volume (Board feet)
80000
70000
60000
50000
40000
30000
20000
10000
Volume - Board Feet
1923
1924
1925
1926
1927
1928
1929
1930
1931
year

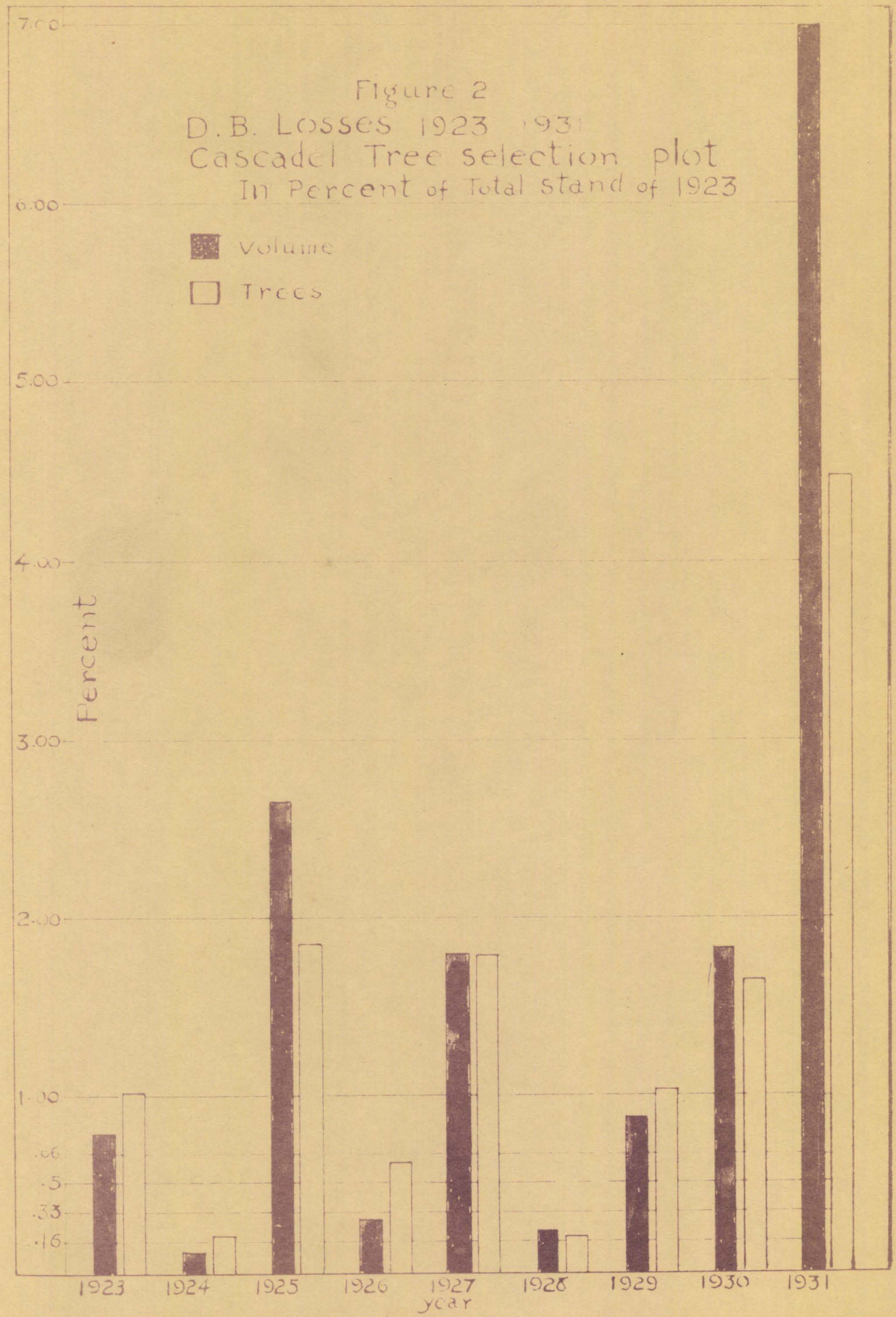


Figure 2
D.B. Losses 1923 1931
Cascade1 Tree selection plot
In Percent of Total stand of 1923
Volume
Trees
7.00
6.00
5.00
4.00
3.00
2.00
1.00
.66
.5
.33
.16
Percent
1923
1924
1925
1926
1927
1928
1929
1930
1931
year

Figure 3.

Annual Losses By D. B. 1923 - 1931 In Volume - Board Feet and Number of Trees On 3 Ten Acre Units of Cascadel Tree Selection plot.

Volume

Number of Trees = Volume ÷ 1000 or see Scale Right

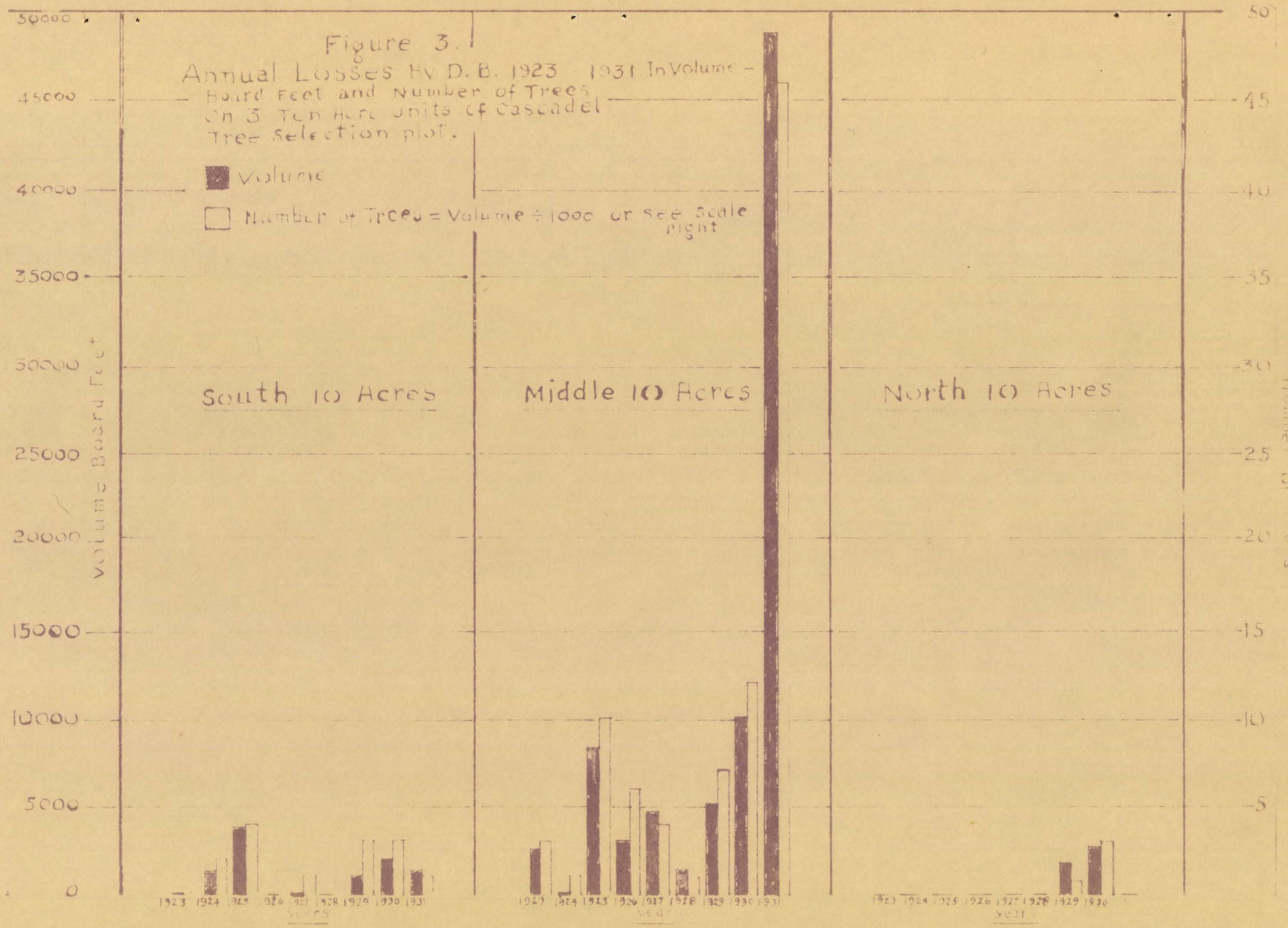


Figure 4

D. b. And other losses 1923 To 1931 on 3-10-Acre Units of Cascadel Tree Selection Plot Shown As Percent of Green Stand Left After Loss For Each Successive year

- □ Trees Killed By D.b.
- ■ Volume " " D.b.
- ▨ Trees Killed By Other causes
- ▨ Volume " " " "

S = South 10-Acres
M = Middle 10- "
N = North 10- "

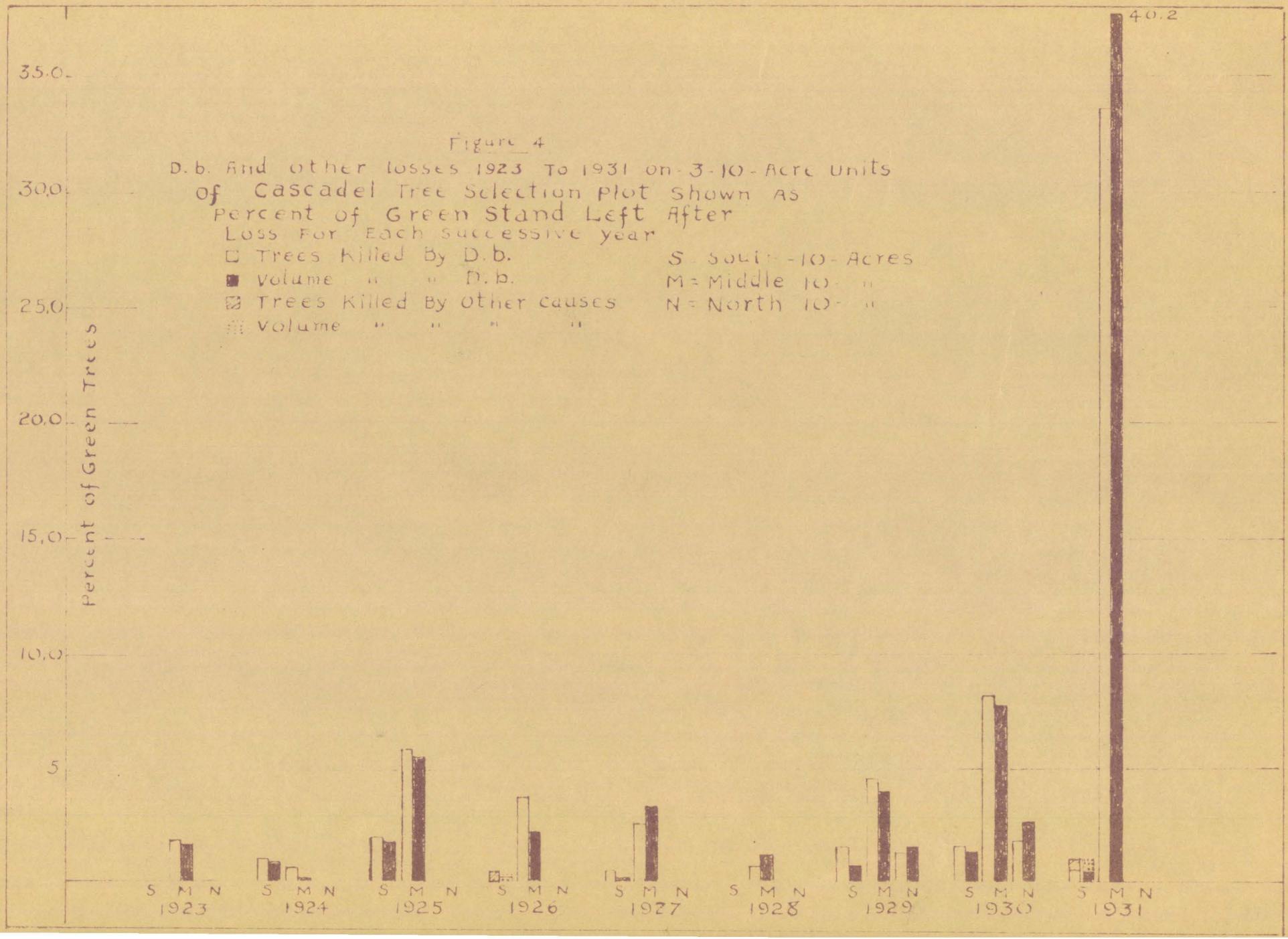


Figure 5

Comparison of D. B. Losses 1923–1931 on Ten-Acre Units of Cascadel Tree Selection Plot Shown in Cumulative Percent of Green Trees in 1923 in each Unit

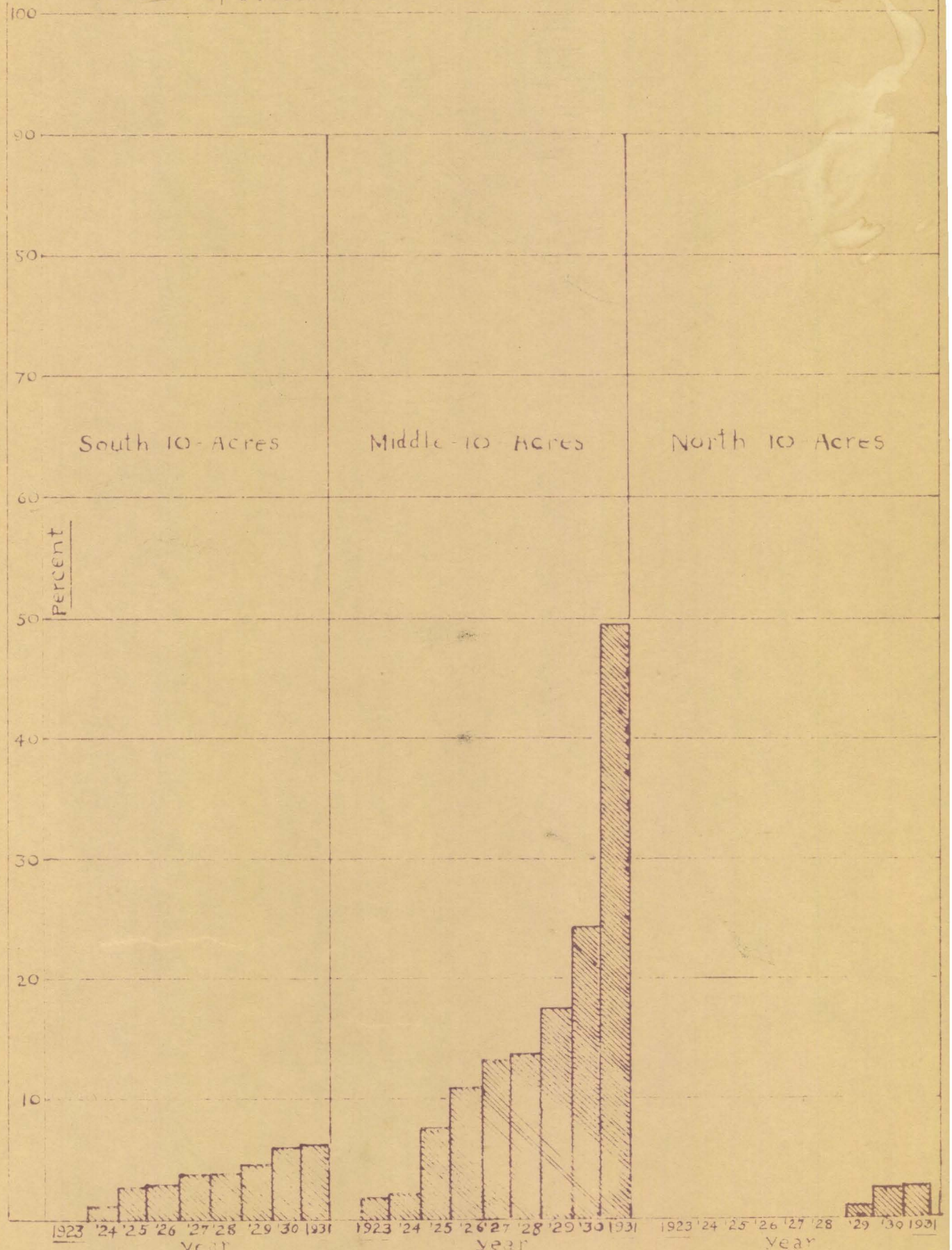


Figure 6.

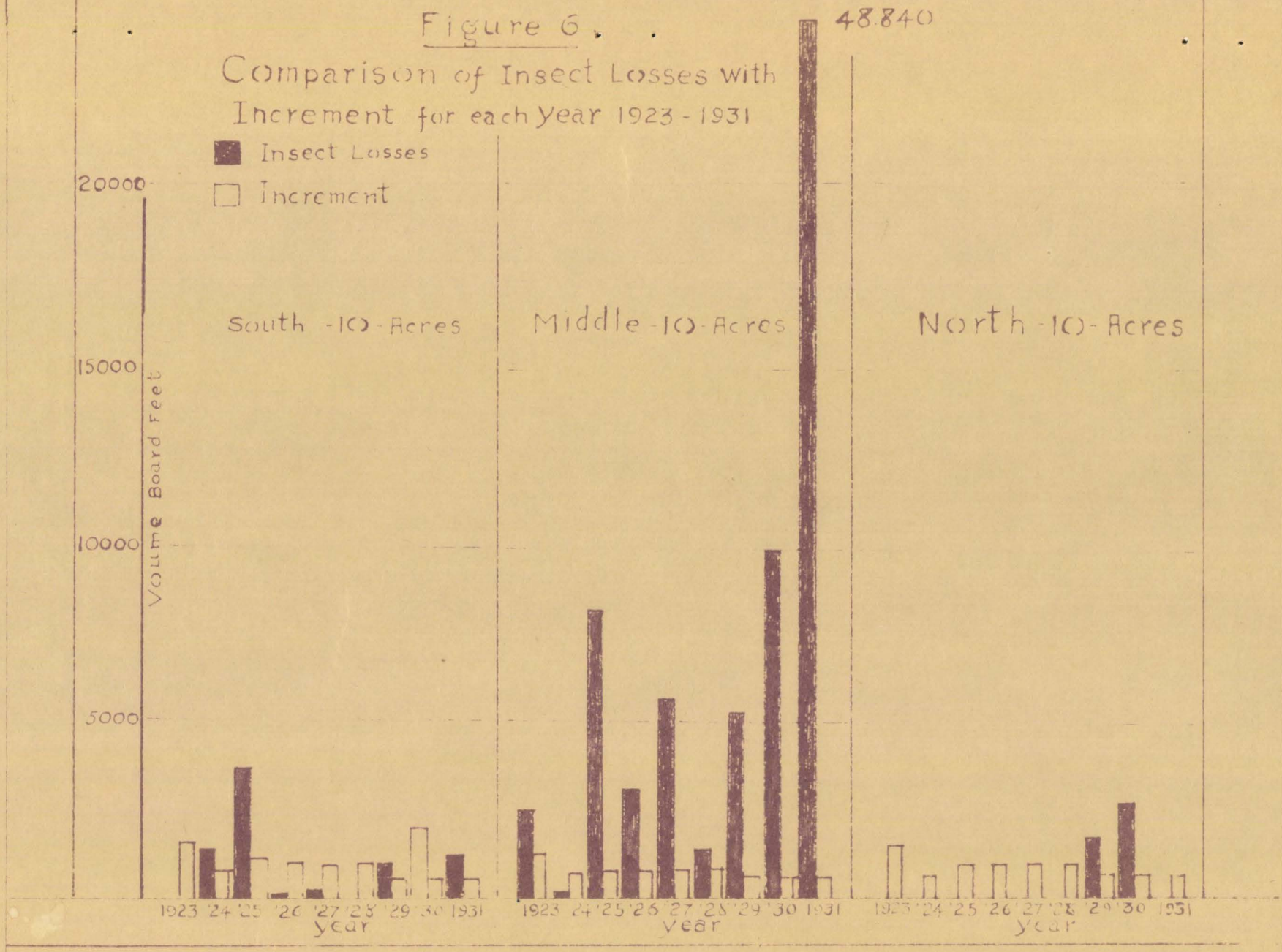

Comparison of Insect Losses with Increment for each year 1923 - 1931
Insect Losses
Increment
48.840
20000
15000
10000
5000
Volume Board Feet
South -10- Acres
Middle -10- Acres
North -10- Acres
1923 '24 '25 '26 '27 '28 '29 '30 1931
year

FIGURE 7

COMPARISON BETWEEN INCREMENT, LOSS, AND NET LIVING VOLUME ON EACH PLOT FROM 1923 TO 1931 IN PERCENT OF ORIGINAL GREEN VOLUME OF 1923

■ GREEN VOLUME ▨ INCREMENT ▥ LOSS

PERCENT OF 1923 VOLUME

100 96 92 88 84 80 76 72 68 64 60 56 52 48 44 40 36 32 28 24 20 16 12 0

SOUTH 10 ACRES

MIDDLE 10 ACRES

NORTH 10 ACRES

1923 1924 1925 1926 1927 1928 1929 1930 1931 1932

YEAR

FIGURE 8
CUMULATIVE CURVES BASED ON VOLUME (BOARD FEET) COMPARISON OF INCREMENT AND LOSS FOR EACH YEAR

—— INCREMENT

- - - - LOSS

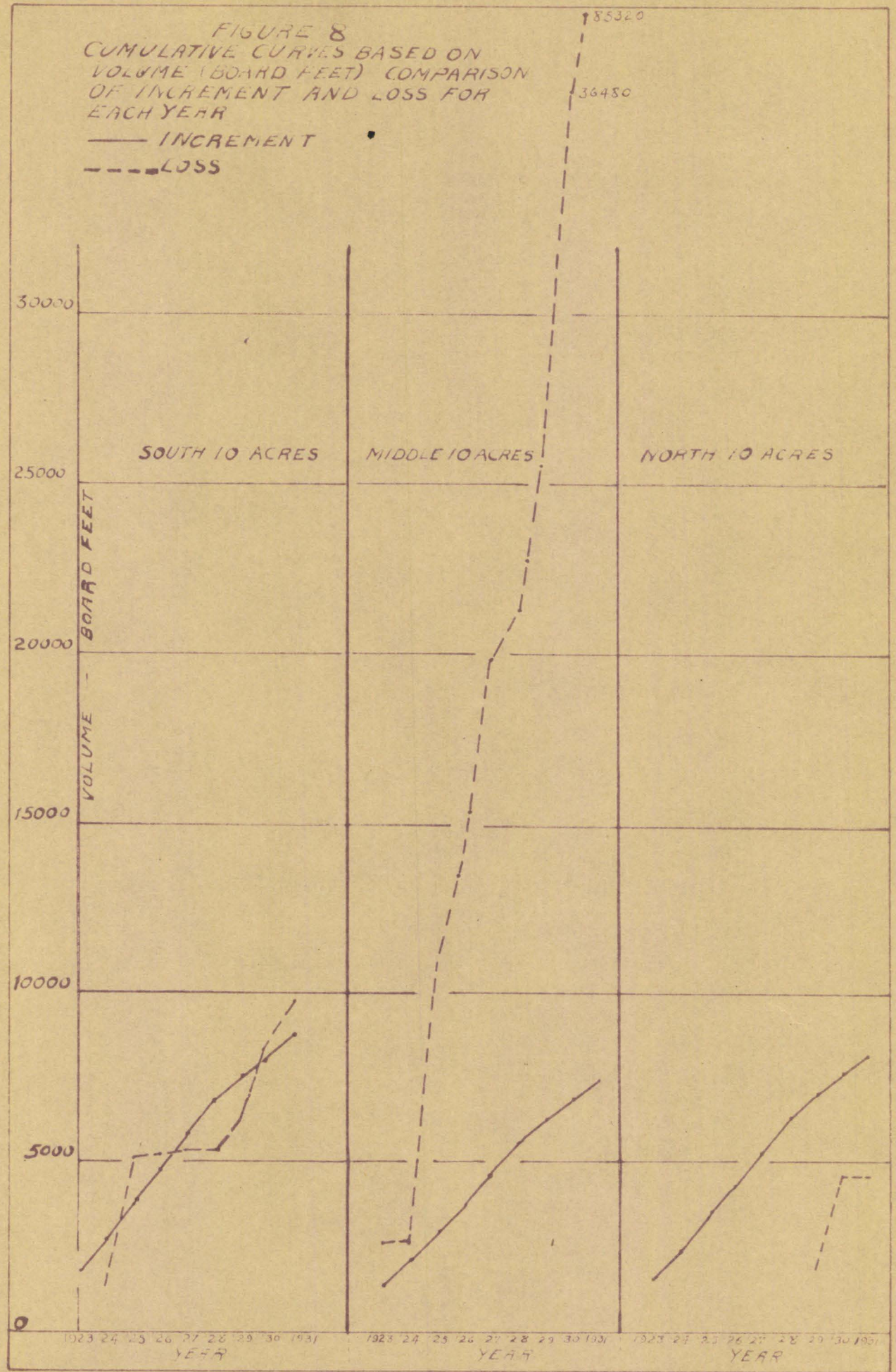


FIGURE 9

GROWTH RATE COMPARISON BETWEEN GREEN AND INSECT KILLED TREES IN EACH OF KEEN'S AGE CLASSES FOR EACH 10 ACRE PLOT FROM 1923 TO 1931 —— GREEN - - - INSECT KILLED

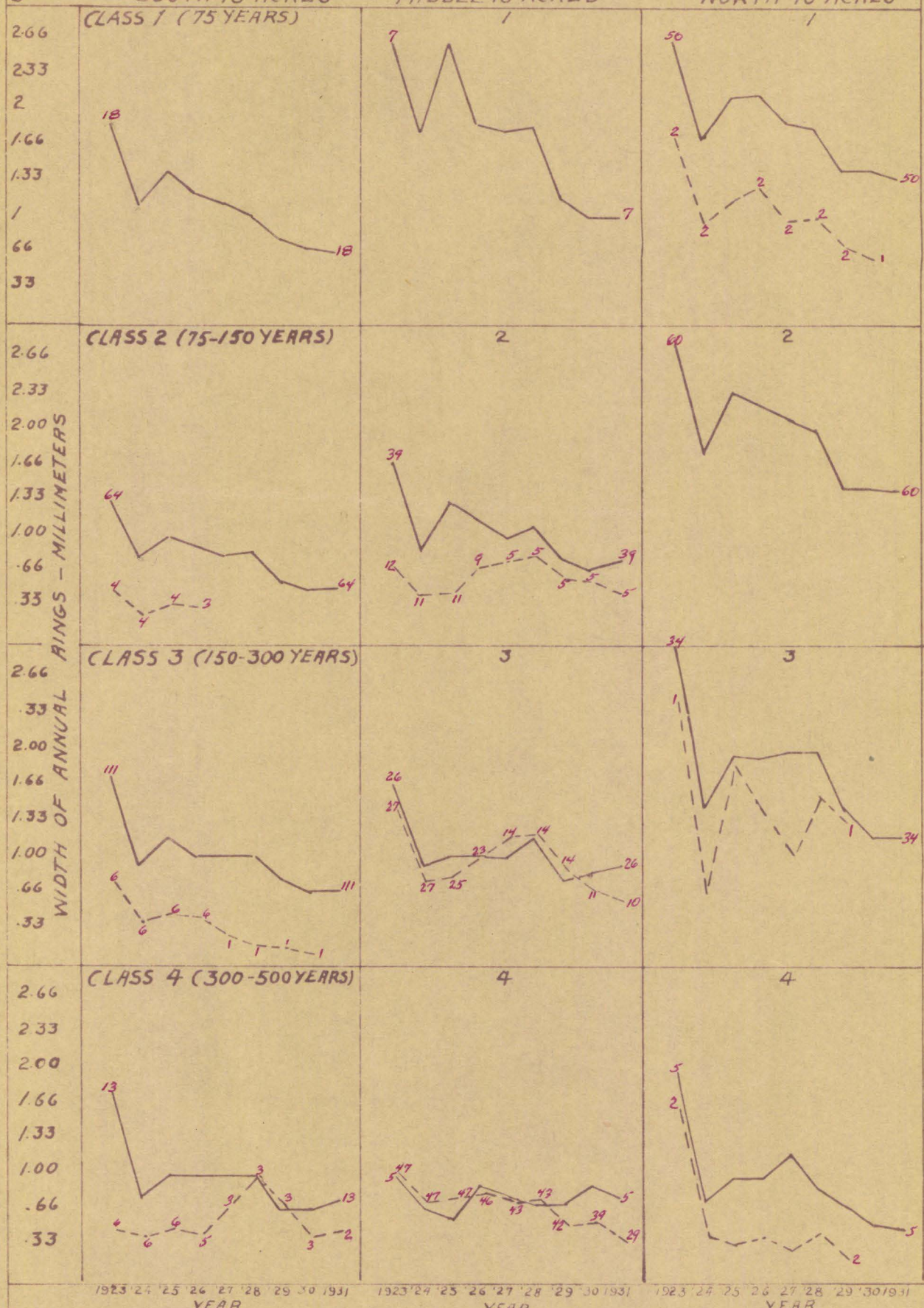


FIGURE 10

AVERAGE GROWTH RATE COMPARISON BETWEEN GREEN TREES AND INSECT KILLED TREES ON EACH 10 ACRE PLOT

—— GREEN - - - INSECT KILLED

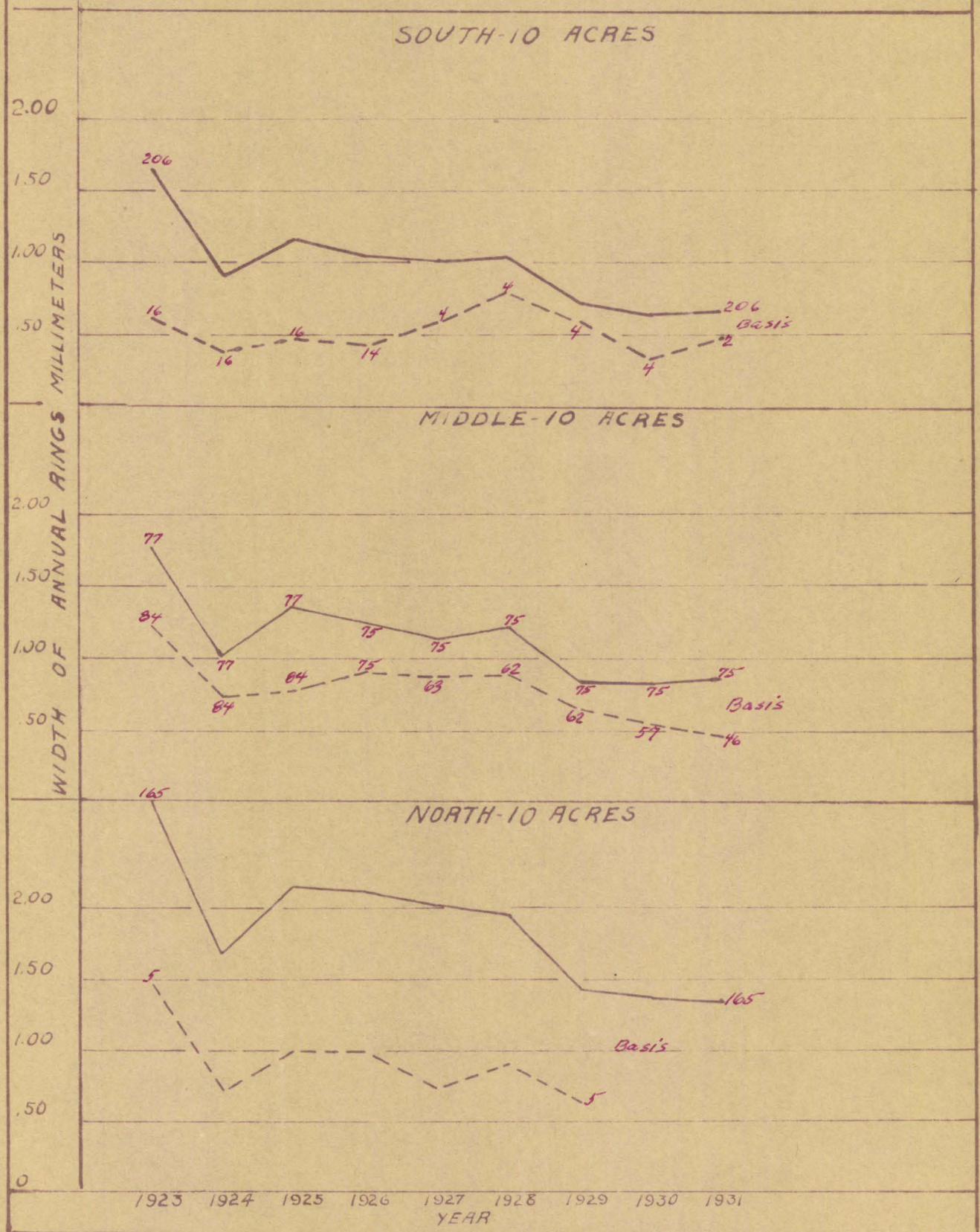
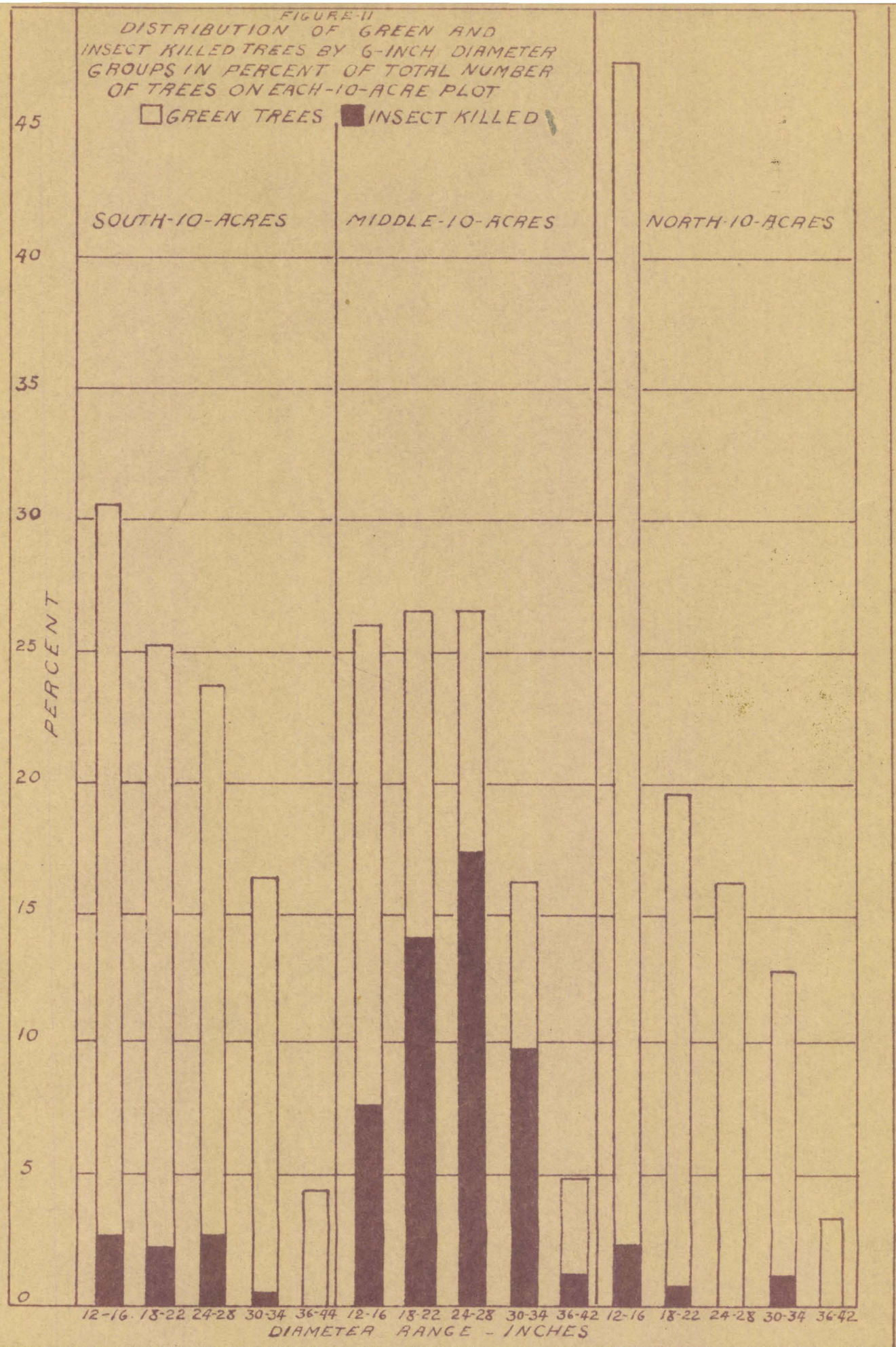


FIGURE-11

DISTRIBUTION OF GREEN AND INSECT KILLED TREES BY 6-INCH DIAMETER GROUPS IN PERCENT OF TOTAL NUMBER OF TREES ON EACH-10-ACRE PLOT



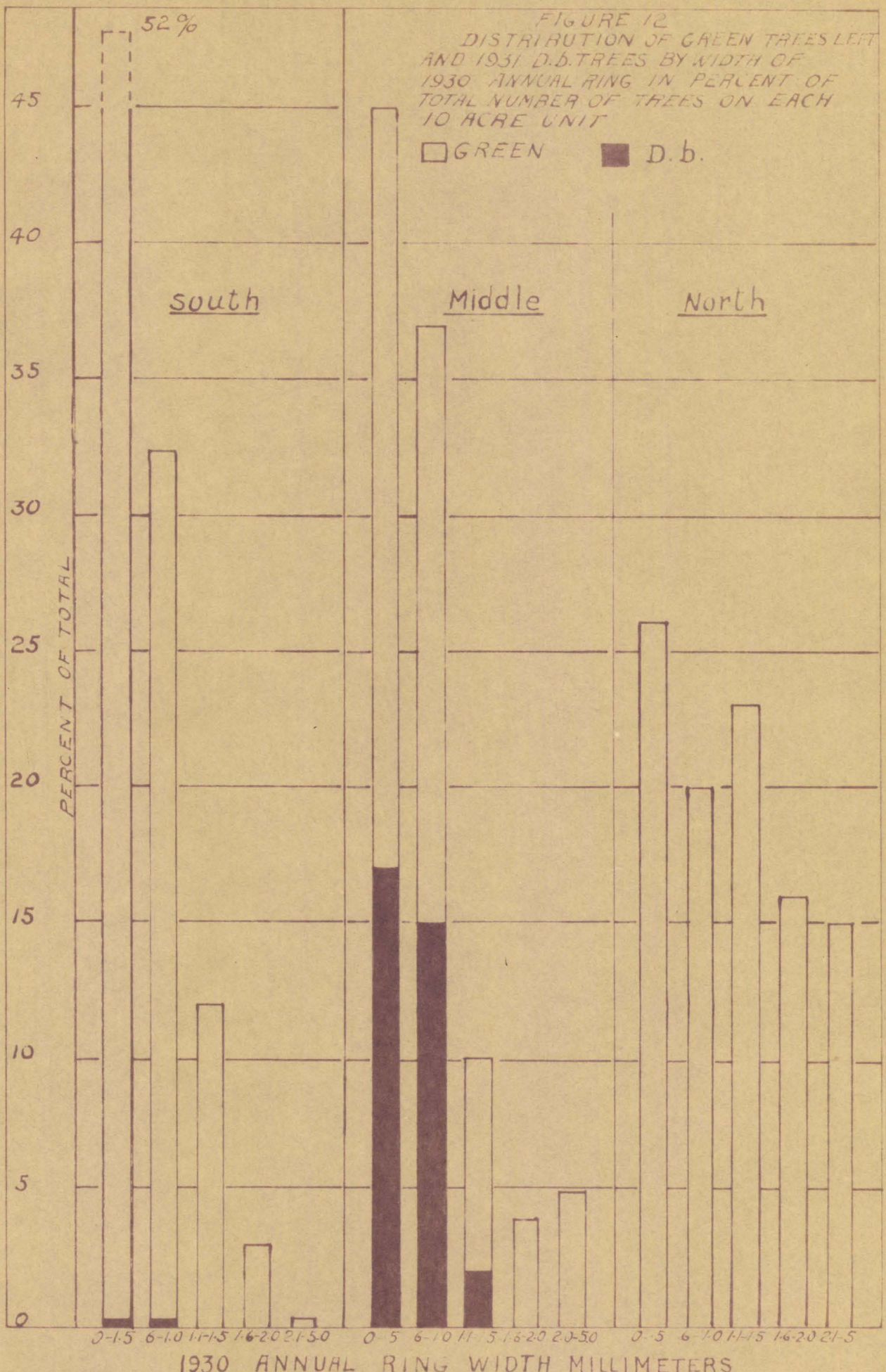


FIGURE 12
DISTRIBUTION OF GREEN TREES LEFT AND 1931 D.b. TREES BY WIDTH OF 1930 ANNUAL RING IN PERCENT OF TOTAL NUMBER OF TREES ON EACH 10 ACRE UNIT
GREEN
D.b.
52%
South
Middle
North
PERCENT OF TOTAL
45
40
35
30
25
20
15
10
5
0
0-1.5
6-10
11-15
16-20
21-50
0-5
6-10
11-15
16-20
20-50
0-5
6-10
11-15
16-20
21-5
1930 ANNUAL RING WIDTH MILLIMETERS